Clean Copy of the Specification

Following Entry of this Amendment

FUEL CELL WITH FUEL DELIVERY DEVICE AND METHOD OF MANUFACTURE

TECHNICAL FIELD

The present invention relates to the field of integrated circuits, and in particular to the field of integrated circuit containing an integrated fuel cell.

BACKGROUND OF THE INVENTION

The electrical power for electrically operated devices, circuits, and the like, is ordinarily supplied by external energy sources. Typical external energy sources are connections to a power network or batteries.

Fuel cell systems can also be used instead of batteries. Fuel cells typically include a first electrode and a second electrode, one of which serves as an anode and the other as a cathode. A membrane-electrode unit (MEU) with catalytic properties is located between the electrodes and serves as a proton-permeable membrane with catalytic coating. Such a fuel cell also has a fuel delivery device for feeding in a fuel, typically hydrogen, and a reactant delivery device for feeding in a reactant. The reactant reacts with protons that originate from the fuel and that have passed through the membrane to generate current.

U.S. Patent 6,312,846 discloses a fuel cell formed on a semiconductor wafer, with channels formed in the wafer as conductors for the fuel and for the reactant, and with a membrane formed between the channels that permits the diffusion of protons. It is a drawback to such systems that an additional separate reservoir connected to the channel conducting the fuel has to be provided.

U.S. Patent 6,326,097 discloses a system designed to recharge the batteries, for example of a mobile radio. This system includes a mount with an electrical connection for the instrument

to be provided with current and a fuel cell system to generate the current to be supplied, as well as a fuel delivery device to feed the fuel into the fuel cell system. The fuel delivery device in this case includes a receptacle for hydrogen storage cartridges, which can be replaced after the fuel is consumed. Such systems are structurally complex and are reasonable for generating a rather large amount of current, for example, as needed by mobile radios.

Also generally known from U.S. Patent 6,160,278 and International Application WO 01/69228 A2 are hydrogen sensors that are fabricated as semiconductor structural units. Palladium (Pd) is used here as the hydrogen-sensitive electrode material.

SUMMARY OF THE INVENTION

A fuel cell comprises a first and a second electrodes, a proton permeable layer, a fuel delivery layer and a reactant delivery layer. The first and the second electrodes are configured to define a reaction region, where the first electrode configured as a cathode and the second electrode configured as an anode. The proton permeable layer is positioned between the first and the second electrodes. The fuel devilery device is configured to provide fuel to the first electrode. The reactant delivery device is configured to provide reactant to the second electrode, where the reactant reacts with protons from the fuel to generate a current. Where the fuel penetrates into the first electrode.

Using, as the fuel delivery device, a layer integrated into the fuel cell into which the fuel is already incorporated provides the benefit that no separate fuel infeed channels or the like have to be provided. This simplifies construction considerably.

According to an alternative embodiment, a fuel cell is provided with a reactant delivery device.

The fuel delivery device may include material contacted by the fuel that releases the fuel or protons generated from it as needed. Palladium is preferably used as the base material for such a fuel delivery device because of its good hydrogen sensitivity, with hydrogen usually being used as the fuel for fuel cells at the present time.

In some examples, the reactant is oxygen, which can be fed in from the atmosphere. The reactant infeed device in the simplest case is therefore a channel or an open surface that communicates with the external space.

A control device may be used to activate the fuel cell or a unit that includes multiple coupled fuel cells of this type. Such a control device on the one hand can be a switch that closes a circuit between the two electrodes of the fuel cell. On the other hand, in another embodiment, a fuel cell can be provided in which the reactant delivery device includes a space that has no reactant, or for example that is evacuated of ambient air. The control device, for example, then includes a window to this evacuated space that can be opened to permit the entry of ambient air and with it oxygen as the reactant, to the fuel cell or its corresponding reaction surface.

The control device, for example, can have a control element such as the switch or the partition to be opened, to trigger an alarm. Alarm devices of this type can be used in many ways, especially to signal a burglary or to signal an emergency for a handicapped person. The alarm signals can be emitted in the usual way, in particular by light signals, acoustic signals, or by radio transmission to an emergency control center. In the latter case, besides transmitting the actual emergency signal, it is desirable also to transmit personal data about the sender and preferably a current position determined, for example, by a GPS (global positioning system).

It is also possible to use such fuel cells as energy reservoirs for recharging electrically operated circuits or devices that consume only minimal current, so that connecting a battery or providing a fuel reservoir can be structurally omitted.

Such a fuel cell with a fuel delivery device can advantageously be integrated directly into a circuit. An advantageous area of use would be CMOS circuits. Use in appropriate electrically operated devices is also advantageous instead of using a battery. An example of such an electrically operated device can be an alarm system in which the fuel cell is replaced after single or multiple activations of an alarm.

Modular construction that permits replacement as a module after one or more uses is particularly advantageous. Such a module may include only a fuel cell with its fuel delivery device, but, for example, may also include a circuit with an integrated fuel cell. Such a module advantageously has connectors, for example plugs that can be inserted into corresponding sockets of a circuit or of an electrically operated device.

Connection of a fuel sensor, especially a hydrogen sensor, is also advantageous for such a fuel cell, with the fuel sensor being in contact with the layer that contains the fuel. A warning signal can be emitted by the fuel sensor in case of decreasing fuel content, which shows that the fuel cell has to be replaced.

Depending on the choice of parallel or series circuitry, coupling multiple fuel cells of this type makes it possible to increase the available current and/or voltage. In this case, multiple fuel cells can be placed on one chip face, and can be wired in parallel through a common multiplex cable.

The fuel cells may also be easily recycled since such cells are structural units made of single pure materials.

The above advantages are also obtained correspondingly for the case of a reactant delivery device. Ideally, such a fuel cell can also have both a fuel delivery device and a reactant delivery device.

Hydrogen is preferably considered as the fuel and oxygen as the reactant. However, any other fuels and appropriate reactants can also be used. In particular, the terms fuel and reactant should be interpreted broadly, for example, where oxygen in the last analysis also to be viewed as the fuel and hydrogen as the associated reactant.

Embodiments are also possible in which both the fuel and the reactant are provided in the electrodes or in materials adjacent to the electrodes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a fuel cell with fuel delivery device mounted on an integrated circuit;

FIG. 2 illustrates a fuel cell in a preferred embodiment in combination with a circuit;

FIG. 3 illustrates another circuit arrangement with a fuel cell and a circuit in a reactant-free space;

FIG. 4 illustrates an alternative embodiment with an alternative electrode structure; and

FIG. 5 illustrates another embodiment with yet another electrode structure and wiring as a sensor.

DETAILED DESCRIPTION

Referring to FIG, 1, a fuel cell 1 includes a first electrode 3 and a second electrode 4, or an appropriate electrode system. The two electrodes 3, 4 are formed at least by one proton-permeable layer 5, preferably in the form of a catalytic membrane. The electrodes 3, 4 are

formed as anode and cathode, respectively, and have electrical connections 8. In the present example, the first electrode 3 is positioned directly on a base 2, so that a direct connection can be made to a corresponding conductive region of the base 2. A contact 8 in the form of a conductor line leads from the second electrode 4 to the surface of the base 2, for example to connect the second electrode 4. The base 2, in some examples, includes on its top, i.e. facing the fuel cell 1, of a polysilicon 6 with appropriate structuring or design of appropriately doped regions. The polysilicon 6 constitutes a transition layer to an integrated circuit 7 (IC) located beneath it that is to be supplied with current from the fuel cell 1.

Fuel that includes hydrogen H_2 escapes from the face of the first electrode 3. The fuel reacts with the catalytic layer 5 or appropriate elements in the material of the first electrode 3 in such a way that hydrogen ions, i.e. protons, are released. These protons pass through the proton-permeable layer 5 toward the second electrode 4. In the region of the second electrode 4, the protons react with a reactant fed to this region, preferably oxygen O_2. When a circuit is closed between the electrical conductors 8, a corresponding current flows through them.

FIG. 1 illustrates one example where the reactant O_2 arrives directly to the freely accessible second electrode 4 from the surroundings, such that the reactant operation is possible in any area with oxygen-containing air. In the present example, the second electrode 4 includes a diffusion layer that permits the entry and passage of the reactant O_2.

The fuel delivery device advantageously includes the first electrode 3 and/or another layer adjacent to it. This first electrode 3 or the other layer contains fuel, for example hydrogen H_2. When needed, the fuel is released from the material of the first electrode 3, in a comparable manner to what is known otherwise from prior art fuel cells from corresponding fuel infeed channels.

The structural advantage and the capability of the small size of the system outweigh the limited amount of available fuel. This may also be true in devices with very low, for example a one-time, current demand since no additional fuel infeed channels or separate fuel reservoirs are necessary.

Manufacturing a fuel cell with the integrated fuel delivery device is particularly simple in a semiconductor production process, for example in a CMOS process. In the present example, a material treated by the fuel is applied to a base layer in the preparation of the layer to develop the first electrode 3 or the other layer adjacent to it. A combination of contacted palladium (Pd) that is treated with hydrogen during or after the deposition process may be advantageous. The membrane or the proton-permeable layer 5 and other materials and layers necessary for a fuel cell are then applied.

For example, the first electrode 3 that includes a palladium layer with an area of 1 mm^2 and 1 μm thick can be saturated with hydrogen during the production process. In one example, no other additional infeed devices for hydrogen or corresponding energy carriers is provided. The oxygen is advantageously fed in from the atmosphere. In another example, a current of 1 μA lasting ten seconds may be generated by a single treatment with hydrogen. Simple semiconductor circuits or chips, for example an alarm system, may be provided with an integrated power source.

In one example, the system is used in circuits and devices used in emergencies.

FIG. 2 illustrates an example of a modular system having a replaceable fuel cell 1 that can be plugged into a base 12. The fuel cell 1, for example, includes the structure described above, so that comparable structural elements need not be discussed again.

Electrical conductors that are located, for example, on the sides of the electrodes 3, 4 and are designed as contact pins 11, connect the first and second electrodes 3, 4. The contact pins 11 lead downward toward the base 12 made as a bottom plate, and pass into and through this base 12 through contact pin receptacles or holes 13. Contacts 14 that make contact between corresponding electrical conductors 15 on or in the base 12 and the contact pins 11 are present in the area of each hole 13. The holes 13 and/or the contacts 14 are of such dimensions and/or are provided with such material, for example, that they offer enough support for the contact pins 11 so that the fuel cell 1 can be positioned removably but sufficiently firmly on the base 12 through the contact pins 11.

The fuel cell 1 serves to supply current to a circuit 16, which is likewise placed on the base 12. The circuit 16 here is supplied with current through the two electrical conductors 15. One of the two conductors 15 leads through a switching device 17, which can be designed, for example, as a simple pushbutton. However, any other form of switching device, in particular light sensor switches, switching devices reacting to acoustic signals, motion detectors, and the like, is also possible as a switch. After activation of the switching device 17, the circuit is closed and the electrochemical process in the fuel cell is activated to supply the circuit 16. Hydrogen H_2, for example, present in the material of the first electrode 3 or in a layer adjacent to it is cleaved, and protons pass through the proton-permeable layer 5 to the second electrode 4, where a reaction with oxygen O_2 from the atmosphere takes place, with current being generated.

If the circuit 16 is, for example, an alarm system, then an alarm can be triggered by the activation of the switching device 17, for example by sounding a warning tone, a light signal, or by transmitting an electromagnetic signal through a radio interface or a wired interface to a receiver, for example in an emergency center.

In addition to the warning information, such a signal can also transmit coded information about the transmitter or its holder, or place of installation, and preferably also position data when used as a portable warning device. Current position information can be provided, for example, by coupling with a GPS receiver.

Alternatively to fastening the fuel cell on the base 12 through the contact pins 11, additional or different fasteners can also be provided. In one example, the fuel cell 1 is fastened to biosensors and the like.

The system advantageously also has a fuel sensor 18, for example a hydrogen sensor, to determine the content or residual content of fuel in the first electrode 3 or in a layer adjacent to it, or both. The fuel sensor 18 includes, for example, an ISFET (ion-selective field effect transistor) with an applied palladium Pd layer or a palladium resistor. This fuel cell sensor 18 is connected by appropriate leads to other circuit components that serve to signal fuel depletion, so that the fuel cell can be replaced as needed.

In one example, the remaining fuel is determined by a circuit that measures the resistance of the fuel delivery device and compares the measurement with test measurements previously made.

FIG. 3 illustrates another example of a fuel cell system. Elements that are structurally identical or equivalent with reference to the above exemplary embodiments are not mentioned again. The system comprises a base 12 on which is mounted a fuel cell 1 with a first electrode 3 containing fuel, a proton-permeable layer 5, and a second electrode 4 mounted on a base 12. Electrical conductors 8, 15 lead from the fuel cell 1 to a circuit 16, likewise positioned on the base 12. The circuit 16 may be, for example, an alarm system, a sensor, a storage device, or the like. In contrast to the previous embodiment, this system does not have an ordinary switching

device that disconnects at least one of the two electrical conductors 15 in the normal state. Instead, the entire system is in a housing 20 whose internal space is free of the reactant necessary for generating current. In the usual example, there would be no oxygen inside the housing 20. To activate the generation of current, there is a region that is closed off in normal operation inside one of the walls of the housing 20, which serves as a switching device 27. By opening this closed-off region, for example by a film that can be pierced or a valve to be opened, atmospheric air and thus oxygen enters the internal space of the housing 20. The opening leads to activation of the electrochemical process and thus to a flow of current through the circuit 16. In another example, the internal space of the housing 20 is evacuated, so that when the switching device 27 is opened all at once or by using the controllable valve in a controlled manner, atmospheric air enters the previously evacuated internal space of the housing 20. Activation of current generation may be expedited in this manner.

In another example, the switching device 27 includes a removable housing or a peelable film that can be formed around the entire system or only around the second electrode 4 or the region in which the reactant can react with the protons.

FIG. 4 illustrates an alternative electrode system. Instead of a one-piece electrode 4 that includes a diffusion layer, the electrode includes multiple parts, for example a diffusion layer 4* and an actual electrode covering 4**. The electrode covering 4** includes a solid electrically conductive material and serves to feed in current or to divert it. The diffusion layer 4* allows the reactant O_2 to enter from the side or appropriate openings in the electrode covering 4**.

FIG. 5 illustrates another example of an electrode system. The entire electrode 4^{o} includes a material that is a good electrical conductor, but which does not allow the passage of the reactant O_2, or allows it only inadequately. Reactant channels 4^{oo} or other passages in the

electrode serve to feed the reactant O_2 to the proton-permeable layer 5, for example a membrane-electrode unit with catalytic properties. The reactant channels 4^{oo} are preferably formed adjacent to the proton-permeable layer 5.

Only structural elements relevant to the principal mode of operation are outlined in the illustrated exemplary embodiments. Other functionally necessary structural elements are to be used in accordance with the knowledge of the individual skilled in the art. For example, a coating that insulates from the reactant can be formed around the lower region of the fuel cell so that access of reactant from the atmosphere to the first electrode may be prevented.

While the above exemplary embodiments are described with a layer delivering the fuel, a layer that delivers the reactant can be formed in addition or alternatively in a corresponding manner, with the fuel then being fed in from the outside.

The structure for this is then essentially as described above. Instead of the fuel, in the present case hydrogen H_2, the reactant, in the present case in particular oxygen O_2, is then introduced into a layer. Appropriately, the reaction region and any region present with a layer that contains fuel are shielded so that no other reactant can penetrate from the outside and trigger the current-producing process.

Accordingly, the fuel is fed in from the outside for operation. In case of a combined method with a layer that feeds in the fuel and one that feeds in reactant, an appropriate switching device is made available that begins the electrochemical reaction after actuation and makes current available.

Such a fuel cell can also be used as a sensor to determine the amount of reactant available in the surroundings. As FIG. 5 illustrates, the strength of the current generated by the fuel cell is

measured, for example, by a measuring device 30. The current is in a direct ratio to the amount of reactant that reaches the fuel cell from the surroundings.

Sensors can thus be used to determine the quantity of a reactant in the surroundings of the fuel cell by determining the amount of current or the voltage of the current generated, and displaying or interpreting this.

Hydrogen may also be considered to be a reactant, with the function of fuel then being taken over by oxygen.

A sensor may also indicate a given condition of the surroundings. In one example, the sensor is used as a warning device, for example to warn of gases containing carbon that do not ordinarily occur in this environment or should not occur for safety reasons. The use of the described layers with integrated fuel or reactant is particularly advantageous in such warning devices. In the usual case, for example, an alarm needs to be triggered only in the emergency of a gas leak. Such warning devices equipped with an external fuel infeed would by uneconomical for this reason. Such a sensor with the integrated reactant or fuel for a limited operating time can thus be used advantageously, especially in areas in which current or fuel is rarely or never needed under normal conditions.

In other examples, sensors may be used in combination with an external fuel or reactant infeed device. A sensor to which the fuel or the reactant is fed continuously through a rechargeable or replaceable gas cartridge or through a fixed installed line can be used to great advantage to measure correspondingly the reactant or the fuel in the surroundings. In another example, the infeed device may make permanent operation possible as a sensor. In another example, the infeed of fuel or reactant may occur continuously to avoid variations, and conclusions can be drawn about the intensity of the reactant or the fuel in the surroundings from

variations of the measured current strength or voltage, directly and without a second variable parameter.

Although the present invention has been shown and described with respect to several preferred embodiments thereof, various changes, omissions and additions to the form and detail thereof, may be made therein, without departing from the spirit and scope of the invention.

What is claimed is: